AD NUMBER

AD454794

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 6 Jan 1965. Other requests shall be referred to Naval Civil Engineering Lab., Port Hueneme, CA.

AUTHORITY

USNCEL ltr, 24 Oct 1974

Technical Note N-678

# FLEXIBLE UTILITY CONNECTIONS FOR UNDERGROUND PROTECTIVE SHELTERS

by

H. Tomita

6 January 1965



U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

FLEXIBLE UTILITY CONNECTIONS FOR UNDERGROUND PROTECTIVE SHELTERS

Y-F011-05-02-304

Type C    Final

by

H. Tomita

ABSTRACT

A brief investigation was made of current flexible utility connection designs for buried protective shelters, design criteria for the connections, and information on differential soil-structure displacements caused by nuclear explosions.

Some designs of flexible utility connections were found, but no design criteria were found. Only a meager amount of information was found on differential soil-structure displacements.

A recommendation is given to evaluate flexible utility connections.

## INTRODUCTION

A requirement necessary for survival in underground protective shelters from nuclear explosions is adequate supply of utilities--water, fuel, electricity, etc. Some shelters are designed to be self-contained. That is, the personnel, equipment, and all necessities for survival are within the same shelter. For other designs, separate utility structures near the shelters are used for storage of the utilities. The utilities are supplied to the shelter by lines such as pipes, conduits and cables. Nuclear explosions subject the utility lines passing through the exterior walls of the shelters and structures to high stresses because of the differential displacements caused by shock waves. These high stresses may cause complete rupture of the utility lines. Thus, flexible connections must be designed and constructed to permit freedom of movement of the utility lines with respect to the walls without causing undue stress in the lines or the walls. Small differential displacements are possible with many types of ordinary utility connections, even those considered rigid, because of the flexibility of materials used for utility lines. However, these connections, in general, are not considered sufficiently flexible for use in protective shelters.

This report describes the investigation conducted to determine what specific designs of flexible utility connections are currently being used for buried protective shelters and what design criteria are being used to design these connections. In this investigation a literature search and contacts with the Army, Navy and Air Force were made to obtain current designs of connections and design criteria. In addition, the literature search included an effort to find the magnitudes of differential displacements between buried structures, utility lines, and surrounding soil caused by nuclear explosions. It is anticipated that the investigation together with a future experimental program will lead to development of inexpensive flexible utility connections which will be capable of withstanding ground motion effects expected to occur at blast shelters and remaining in service.

## FLEXIBLE UTILITY CONNECTIONS

### Design

A literature search plus contacts with the Army, Navy and Air Force revealed that there were some designs of flexible utility connections for protective shelters. The connection shown in Figure 1 was used for the utility line passing through the exterior and interior walls of experimental structure No. 3.3c tested during Operation Plumbbob.[1] Figure 2 shows details of three more utility connection designs forwarded by the Bureau of Yards and Docks. The connection shown in Figure 2(a) was designed for the Canadian Department of National Defense, Figure 2(b) for a BUDOCKS microwave tower, and Figure 2(c) for the protective shelter at the Bethesda Naval Medical Center. It appears from Figure 2 that (a) and (b) can tolerate only a relatively small differential displacement compared to (c). The connections shown in Figures 3 through 5 were designed for a launch control and launch facilities of an underground missile site.

Inspection of Figures 1 through 5 shows in general that flexibility of connections is obtained by passing the utility line through an oversized sleeve attached to the wall or protecting the utility line from the surrounding soil. The remaining space in the oversized sleeve is usually filled with some packing material. The protection is afforded by encasing the utility line in an oversized rigid collar which is attached to the wall and extends a short distance away from the shelter.

At the Nevada Test Site (NTS) various types of shelters and utility installations were evaluated during nuclear weapons effects tests. The shelters included steel arch and concrete structures as well as one- and two-story conventional aboveground houses made of wood, brick and concrete.[1-6] Conduits for electrical cables and pipes for ventilation, water, gas, and drainage were incorporated in some of the shelters. However, the displacements of the utility lines were not measured, and only qualitative results were given concerning the effects of nuclear explosion on these lines. In addition, flexible utility connections, if used, were not reported except for the one shown in Figure 1. It was reported that no significant physical damage occurred to the plumbing and electrical fixtures installed in the shelter with the connection shown in Figure 1 at the 60-psi overpressure range.[1] Thus, it appears likely that the connection shown in Figure 1 with the 2-inch clearance between pipe and sleeve was sufficient for the differential displacement caused by the 60-psi overpressure. A flexible utility connection similar to the one shown in Figure 1 was incorporated in a design of 100 psi personnel shelter for the Federal Civil Defense Administration.[2]

The utility installations evaluated at NTS included aboveground and belowground gas installations, electric power installations, and various types of commercial communications equipment. The maximum overpressure for these tests was approximately 5 psi. It was reported that underground gas installations, service piping, regulators, meters to buildings and piping in buildings were apparently undamaged and operative.[6] Slight leakage was reported at jute and lead-caulked cast iron bell and spigot joints.[6] Little damage occurred to an aboveground liquid petroleum bulk storage plant.[7] Damage to electric power installations was confined to the transmission and distribution circuits and was such that the damaged circuits could easily and quickly be repaired.[8] The transmission circuit consisted of a 600-foot span of three copper conductors suspended on steel towers with reinforced concrete footings. The distribution circuit consisted of conductors and transformers mounted on wood poles and service drops to houses. In general, the commercial communications equipment was more resistant to the effects of nuclear explosion than the structures in and near which the equipment was exposed.[9]

In the evaluation of the utility installations at NTS no tests of any flexible utility connections were reported. Evidently, ordinary connections were employed where connections of utility lines to structures were made.

### Design Criteria

While the investigation revealed the existence of some designs of connections, no design criteria have been found. This seems unreasonable since the designs should logically have been based on some established criteria. However, the need for flexible utility connections, especially for underground missile sites, probably resulted in the designs before any criteria could be formulated. Then, too, the information on the differential displacements between buried structures, utility lines, and the surrounding soil induced by nuclear detonation is needed in formulating design criteria for flexible utility connections. The paucity of such information probably delayed the formulation of design criteria.

## GROUND MOTION

A literature search was conducted in an effort to determine the magnitudes of differential displacement between buried structures and surrounding soil when subjected to the effects of nuclear weapons. Information on free-field ground motion was included in this search. Most of the available experimental data on free-field ground motion obtained at the Nevada Test Site (NTS) and Eniwetok Proving Ground (EPG) can be found in various nuclear weapons test reports.[10] Comprehensive reports are also available on the various methods of determining ground motion parameters.[11,12] Thus, detailed discussion of the magnitudes of free-field ground motion is not included herein. Only a brief discussion of the ground motion phenomena is given in the following paragraphs.

The magnitude of ground motion or soil displacement when subjected to dynamic forces depends on the yield of the nuclear weapon, position of the weapon (above, below, or at the ground surface), distance from the weapon to the point of interest, and the physical properties of the ground medium.

For surface and belowground detonations, a considerable portion of the energy is directly transmitted to the ground. The ground motion induced by this process is called directly-induced ground motion. For surface, aboveground and belowground detonations in which cratering occurs, air shock is developed. This air shock travels away from ground zero and induces ground motion by imposing compression and shear waves in the ground. Ground motion induced in this manner is called air-blast induced or air-induced ground motion.

Air-induced ground motion is divided into two distinct regions of behavior. Near ground zero, the air shock velocity is greater than the compression waves in the ground. The ground motion in this region is called superseismic. In this region, the ground motion is controlled by the surface overpressure-time variation directly above the point of interest. The initial ground disturbance is caused by the arrival of air shock wave before any waves are transmitted through the ground.

The relative effect of the air-induced and directly-induced ground motions is not completely understood. The reflected and refracted ground waves may offset or couple with the air-induced waves to decrease or increase the ground motion.

The air shock velocity decreases with increase in distance from ground zero. In the region where the air shock velocity is lower than that of the ground shear wave, the ground motion is called subseismic. This region is characterized by the arrival of ground waves before the air shock. The response of the ground to the various components of the refracted and reflected waves is complicated and not easily predicted.

## DIFFERENTIAL SOIL-STRUCTURE DISPLACEMENT

When a structure is placed in the ground medium, other factors which are additional to those already mentioned are introduced. These factors, which further complicate the phenomena, are the type, size, shape, mass, orientation, method of construction, depth and distance of the buried structure from ground zero.

When this soil-structure system is subjected to dynamic forces, a series of complex changes occur in the intensity and distribution of the contact pressures between the structure and surrounding soil. These changes are influenced by the reflection of the stress waves at the soil-structure interface and also by arching of the soil. All aspects of this complex phenomena are known as "soil-structure interaction" which is a subject of intense study by many researchers.

The literature search indicated that little information is available on the magnitudes of differential soil-structure displacement. Only a few scattered test data are available from nuclear weapons effects tests at NTS and EPG. Most of the measurements concerning motions or displacements have been those for the free-field or those between structural components but not structures with respect to the surrounding soil. However, the need for the information has been recognized, and recommendations have been made to obtain relative displacements of structural components with respect to an undisturbed point in the soil as a function of time.[1, 13]

During Operation Teapot at NTS, two buried structures were subjected to an underground nuclear explosion. These structures were 12-1/2 feet square by approximately 9 feet high reinforced concrete boxes with no roof or floor. Two opposite walls of each structure were 2 feet thick and the others 12-1/2 inches thick. The structures designated as a-1 and a-2 were located approximately 50 and 100 feet respectively from the edge of the crater formed by a 1.2 kt device buried at a depth of 67 feet. The corresponding horizontal distances of the structures from ground zero were 200 feet and 250 feet. The top of the structures was 3 feet 9 inches below the surface of the ground. Figure 6 shows the permanent horizontal displacements of the structures and surrounding soil. The soil displacements were measured under another project. It was reported that the structures responded as rigid structures and essentially moved with the surrounding soil.[14] The measured acceleration versus time curves shown in Figure 7 for the structures and the soil were similar and gave further evidence that the structures and soil moved together.[14] From these results it was concluded that utility lines to the structures probably will not suffer too much damage at the juncture to the structure.[14]

During Operation Plumbbob at NTS three buried structures were subjected to a 37 kt air burst nuclear weapon. These structures were 25-foot diameter, 180-degree corrugated metal arches covered with 5 feet of soil above the crown. Two of the arches (Nos. 3.3b and 3.3c) were located where the peak overpressure on the ground surface was 60 psi, and the other (No. 3.3a) was located at the 100-psi overpressure range. Preshot and postshot measurements of the footing relative to the floor showed an average downward displacement of 2-7/16 inches for the footing of the No. 3.3a structure at the 100-psi overpressure range and 1-1/2 inches for the footings of the Nos. 3.3b and 3.3c structures at the 60-psi overpressure range.[1] Absolute displacements of the floors were not measured. However, the low acceleration readings indicated that the floor slabs experienced only small displacements. Free-field ground motions caused by the air shock from the same 37 kt air burst were measured under another project at the 120- and 59-psi overpressure ranges. The residual displacement was 0.1 inch downward at the 120-psi overpressure range and 0.18 inch upward at the 59-psi overpressure range.[15] These measurements were recorded at a depth of 30 feet from the ground surface. It appears from these results that the footings of the arches punched downward with respect to the free-field which had small displacements. Assuming that the floor had no displacement, the residual differential displacement of the footing was approximately 1-3/4 inches and 2-1/4 inches respectively at the 60- and 100-psi overpressure range.

During Operation Plumbbob, shock gages were installed in the free-field and also on the floor of a rectangular reinforced concrete shelter to measure the maximum displacements at various frequencies. Each shock gage essentially consisted of 10 masses attached to cantilever springs mounted on a vertical plate. The natural frequencies of the spring-mass system ranged from approximately 3 to 300 cycles per second. Peak responses to the shock input were recorded on smoked record plates by a stylus attached to each mass. Figures 8 and 9 show the vertical and horizontal displacement shock spectra for the floor of the shelter and the free-field adjacent to the shelter. The vertical displacements in the shelter were considerably less than the free-field measurements, but the shelter and free-field displacements in the horizontal direction were approximately the same.[4] These results indicated that there was differential soil-structure displacement in the vertical direction but not in the horizontal direction.

Under Task Y-F008-08-02-108, "Model Studies of Soil-Structure Interaction," DASA 13.018, small flexible arch structures were buried in dry sand and subjected to air blast loads up to approximately 25-psi overpressure in the NCEL blast simulator pit. The displacements of the footings and the sand were monitored with deflection gages. Figure 10 shows the peak and permanent differential displacements of the footing and the sand adjacent to the footing. Figure 10 shows in general that the differential displacements increased with increase in overpressure. The increase was approximately linear and the peak differential displacement was slightly greater than the permanent differential displacement. Under the soil-structure interaction task, flexible cylinders were tested similarly as the arches. Unpublished data indicated that the downward displacements of the cylinders were greater than those of the sand.

Other experiments were conducted in the NCEL blast simulator pit under Task Y-F008-08-02-112, "Structural Failure from Ground Motion," DASA 13.018. In these experiments inclusions fabricated out of concrete and wood were buried in dry sand and subjected to dynamic overpressures up to approximately 25 psi. The displacements of the inclusions and the sand at various depths were monitored with deflection gages. Unpublished results indicated in general that the inclusions moved downward more than the sand. The results also indicated that the heavier inclusion was displaced more than the lighter inclusion.

To gain more knowledge of soil and structural displacements under dynamic forces, a study is being made by the University of Illinois under Contract No. NBy-32279. One of the requirements of this contract is to determine the gross magnitude of relative motion between buried structures and their associated auxiliary systems. The results of the study are forthcoming.

## SUMMARY

A brief investigation was conducted to find current designs of flexible utility connections for buried protective shelters, design criteria for the connections and information on differential soil-structure displacements caused by nuclear explosions.

Literature search and contacts with the Army, Navy, and Air Force revealed that there are some designs of flexible utility connections; however, no design criteria have been found. Various types of shelters and utility installations have been evaluated during nuclear weapons effects tests at NTS and EPG, but no flexible utility connections except for one type was found to have been incorporated in the installations.

A literature search indicated that the amount of information is meager on the magnitudes of differential displacement between buried shelters and surrounding soil. The available experimental results gave indications that differential displacements of high magnitudes can occur especially at high overpressures. However, it appeared that the results are not sufficient to formulate realistic design criteria for flexible utility connections. Additional information, especially at high overpressures, is needed. Investigations are being conducted to obtain the needed information at NCEL under Task Y-F008-08-112, "Structural Failure from Ground Motions," DASA 13.018, and also at the University of Illinois under Contract No. NBy-32279.

## RECOMMENDED EXPERIMENTAL PROGRAM

It appears from this investigation that there is a need for evaluating currently available and future designs of flexible utility connections for buried shelters. The evaluation will aid in the development of reliable and economical connections. Therefore, it is recommended that an experimental program as outlined in the subsequent paragraphs be initiated to evaluate the connections.

The experimental program for this task consists of fabricating and testing current flexible utility connection designs. NCEL blast simulator will be used for the tests. The fabricated connections will be incorporated into a simulated section of a footing or end wall of a standard Navy arch structure. Figure 11 shows a proposed test setup. The short lengths of the utility lines passing through the footing section will be pressurized with water, air or have electric cables running inside the lines. On one side of the footing simulated static overburden pressure will be applied on the surface of the sand. This will be accomplished by pressurizing a rubber bag contained by the sand, walls of the simulator pit, the footing and a top platform which is tied to another platform at the bottom of the pit. Static overburden pressures up to 15 psi (approximately equal to 20 feet of dry sand) are possible with this scheme.

A similar experimental setup has been used for the strip footing tests with overburden at NCEL under Task Y-F008-08-03-402, "Fundamental Behavior of Soils Under Time Dependent Loads," DASA 13.018. Most of the apparatus used for those tests can be used for this experimental program without any modifications.

The footing section with the connections will be subjected to the dynamic loads generated in the NCEL blast simulator chamber. The displacements and accelerations of the footing section and utility lines will be measured. In addition, the dynamic loads on the footing section will be monitored. Changes in the footing deflection from test to test will be attained by varying the dynamic load on the footing section. Unpublished test results of the strip footing studies under Task Y-F008-08-03-402 indicated that footing displacements up to approximately 4 inches are possible. The performance of each connection will be evaluated on the basis of its ability to withstand the differential displacements without leaking or without damaging the electrical cables within the utility line.

REFERENCES

1. Operation Plumbbob, Project 3.3, WT-1422, Evaluation of Buried Corrugated-Steel Arch Structures and Associated Components, by G. H. Albright, et al. Headquarters Field Command, DASA, Sandia Base, Albuquerque, New Mexico, 28 February 1961, p. 82, 20, 21, 23.

2. Operation Teapot, Projects 34.1 and 34.3, WT-1218, Evaluation of Various Types of Personnel Shelters Exposed to an Atomic Explosion, by L. J. Vortman, Sandia Corporation, Albuquerque, New Mexico, Federal Civil Defense Administration, Battle Creek, Michigan, 10 May 1957, p. 85.

3. Operation Plumbbob, Project 30.6, WT-1453, Test of French Underground Personnel Shelters, by E. Cohen and N. Dobbs, Ammann and Whitney, New York, New York, 19 June 1962.

4. Operation Plumbbob, Project 30.7, WT-1454, Test of German Underground Personnel Shelters, by E. Cohen and A. Bottenhofer,, Ammann and Whitney, New York, New York, 25 June 1962, p. 76.

5. Operation Teapot, Project 31.1, WT-1194, Damage to Conventional and Special Types of Residences Exposed to Nuclear Effects, by P. A. Randall, Office of Civil and Defense Mobilization, Washington, D.C., 12 April 1961.

6. Operation Teapot, Project 35.4b, ITR-1176, Effects of a Nuclear Explosion on Typical Natural and Manufactured Gas Underground and Aboveground Installations, Including Appliances in Houses, by G. Corfield, American Gas Association, New York, New York, Federal Civil Defense Administration, Battle Creek, Michigan, May 1955, p. 21.

7. Operation Teapot, Project 35.4a, WT-1175, Effects of a Nuclear Explosion on Typical Liquefied Petroleum Gas (LP Gas) Installations and Facilities, by P. W. Tucker and G. R. Webster, Liquefield Petroleum Gas Association, Chicago, Illinois, Federal Civil Defense Administration, Battle Creek, Michigan, 25 June 1957, p. 39.

8. Operation Teapot, Project 35.1, ITR-1173, Effects of Atomic Weapons on Electric Utilities, by V. H. Wood, A. C. Werden, Jr., R. L. Berg, Edison Electric Institute, 420 Lexington Avenue, New York, New York, Federal Civil Defense Administration, Battle Creek, Michigan, May 1955, p. 3.

9. Operation Teapot, Project 35.2, ITR 1193, The Effects of a Nuclear Explosion on Commercial Communications Equipment, by R. H. Williamson, Radio-Electronics-Television Manufacturers Association, Washington, D.C., Federal Civil Defense Administration, Battle Creek, Michigan, May 1955, p. 3.

10. Operation Plumbbob, Project 1.4, WT-1404, Ground Acceleration, Stress, and Strain at High Incident Overpressures (U), by L. M. Swift, D. C. Sachs and F. M. Sauer, Headquarters Field Command, DASA, Sandia Base, Albuquerque, New Mexico, 10 May 1960, pp. 124-126. FORMERLY RESTRICTED DATA.

11. Air Force Special Weapons Center. TDR-62-138, Air Force Design Manual, Principles and Practices for Design of Hardened Structures, by N. M. Newmark and J. D. Haltiwanger, Kirtland Air Force Base, New Mexico, December 1962, pp. 4-1 to 4-90.

12. Defense Atomic Support Agency, DASA-1285 (IV), Nuclear Geoplosics, A Sourcebook of Underground Phenomena and Effects of Nuclear Explosions, Part Four--Empirical Analysis of Ground Motion and Cratering, by F. M. Sauer, G. B. Clark, and D. C. Anderson, Washington 25, D.C., May 1964, pp. 1-64.

13. Operation Plumbbob, Project 3.2, WT-1421, Evaluation of Buried Conduits as Personnel Shelters, by G. H. Albright, J. C. LeDoux and R. A. Mitchell, Headquarters Field Command, DASA, Sandia Base, Albuquerque, New Mexico, 14 July 1960, p. 43.

14. Operation Teapot, Project 3.3.2, WT-1126, Behavior of Underground Structures Subjected to an Underground Explosion, by G. K. Sinnamon, et al, Headquarters Field Command, Armed Forces Special Weapons Project, Sandia Base, Albuquerque, New Mexico, 11 October 1957, p. 49.

15. Operation Plumbbob, Project 1.5, WT-1405, Ground Motion Studies at High Incident Overpressure, by W. R. Perret, Headquarters Field Command, DASA, Sandia Base, Albuquerque, New Mexico, 20 June 1960, p. 55.

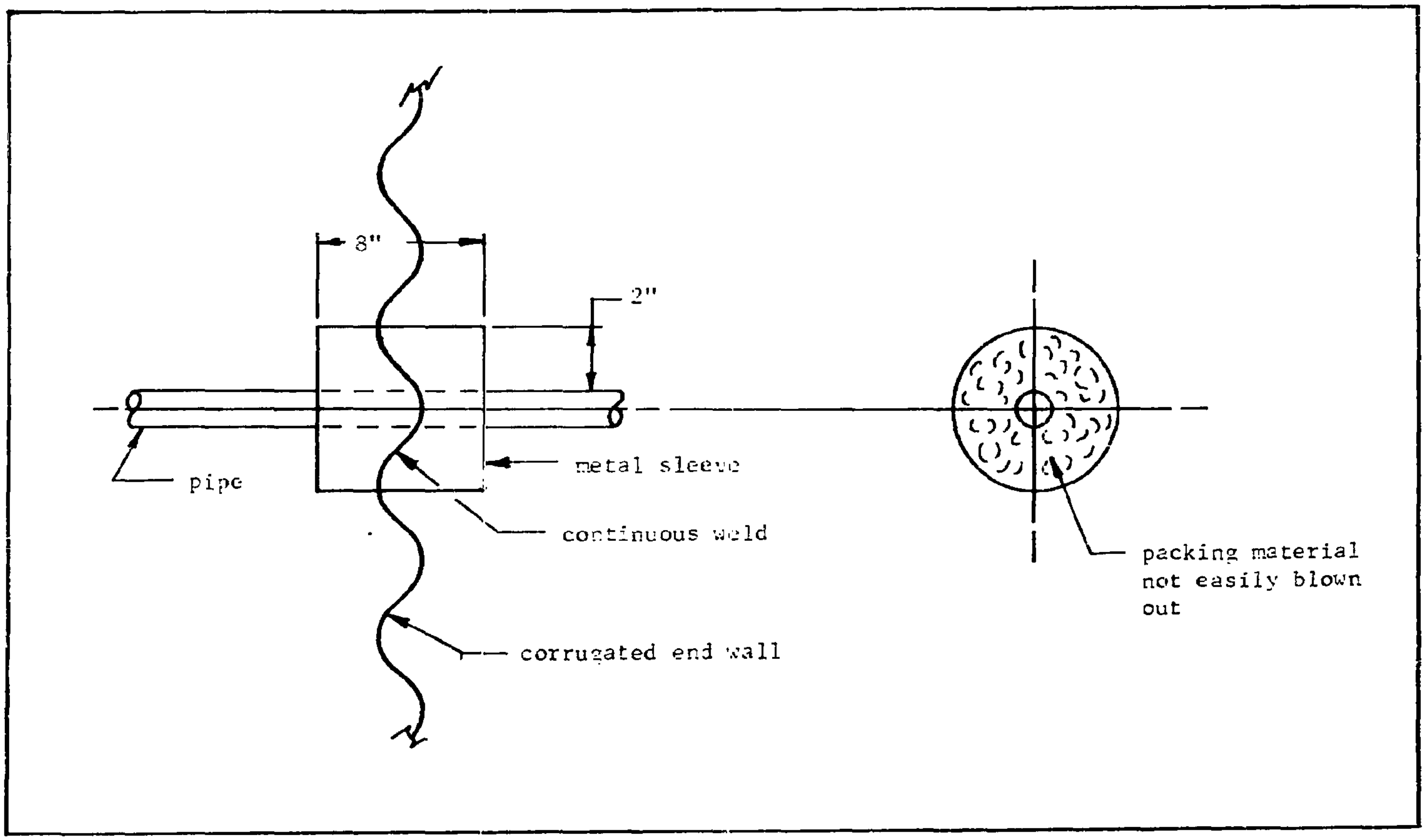



Figure 1. Flexible connection for pipe through end wall of Plumbbob 3.3a structure (reference 1).

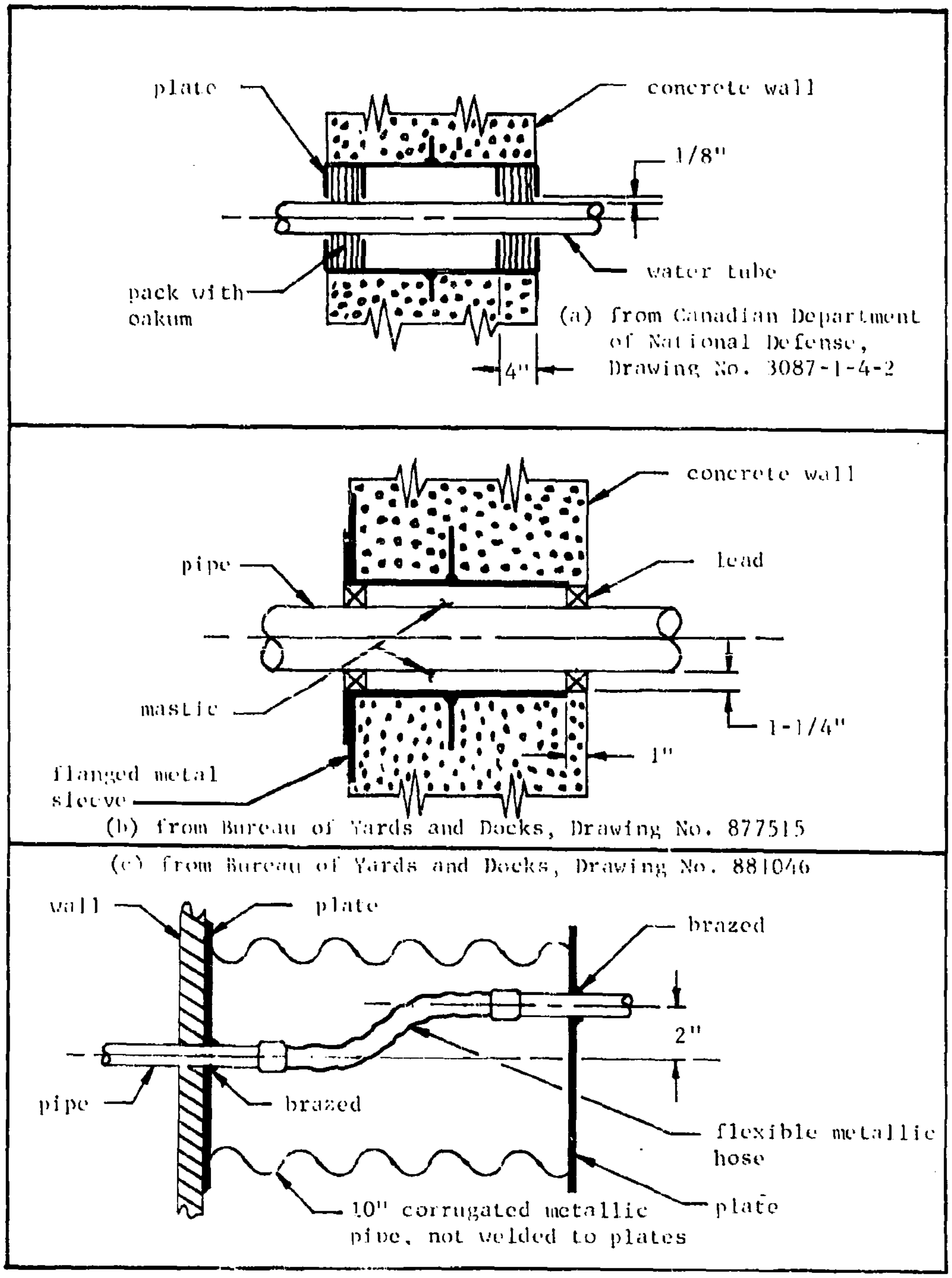
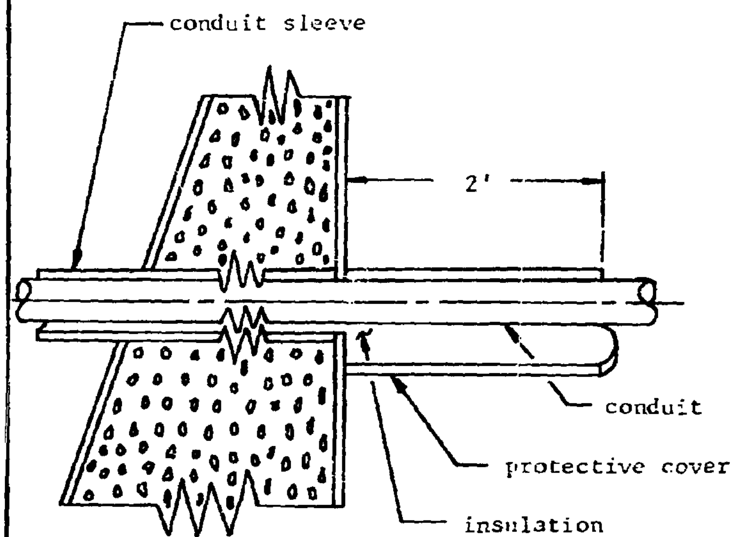



Figure 2. Details of utility connection designs.
forwarded by BUDOCKS.




| Hardened Conduit Entrance Schedule | | |
|---|---|---|
| Conduit Size | Conduit Sleeve Schedule 40 Pipe | Protective Cover Schedule 80 Pipe |
| 3/4 & 1" | 2" | 5" |
| 1-1/4" | 2-1/2" | 5" |
| 1-1/2" | 2-1/2" | 5" |
| 2" | 3" | 6" |
| 2-1/2" | 3-1/2" | 6" |
| 3" | 4" | 8" |
| 4" | 5" | 8" |
| 5" | 6" | 10" |
| 6" | 7" | 10" |

Figure 3. Hardened conduit entrance for launch control facility.

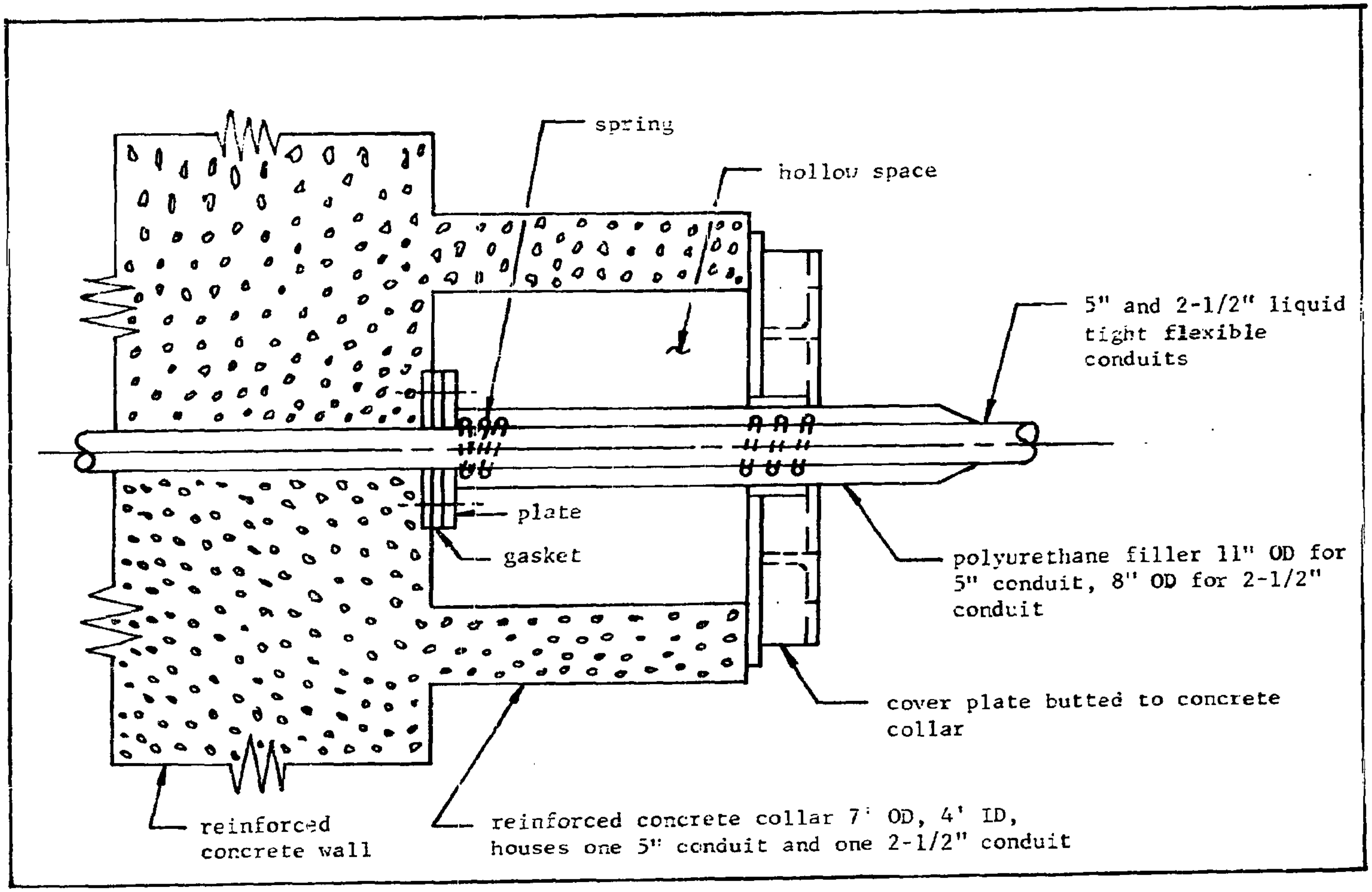
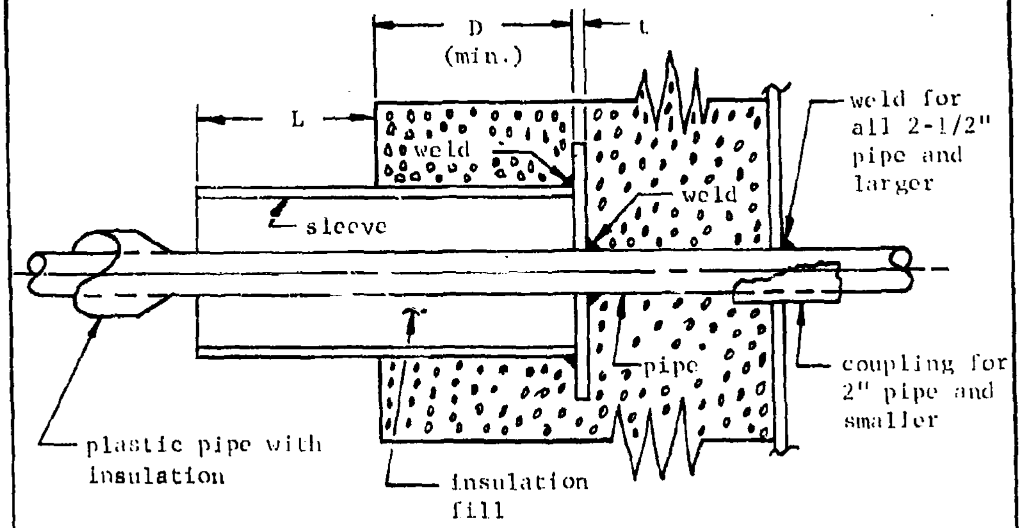


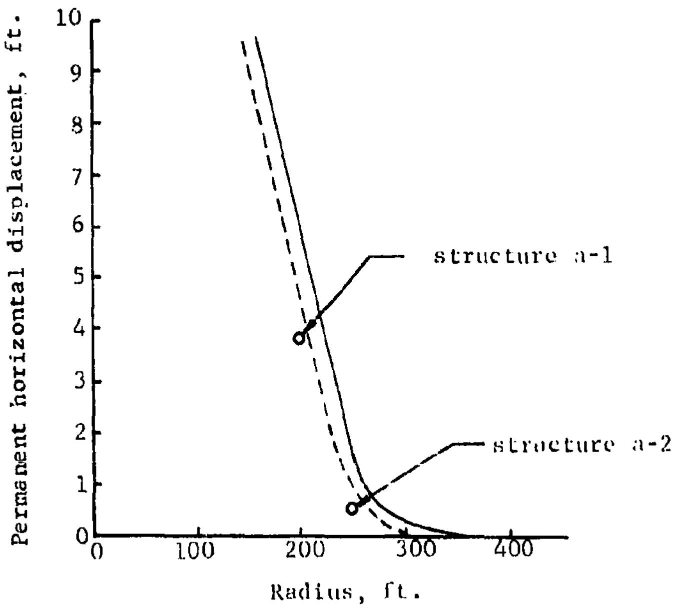

Figure 4. Antenna cable entrance for launch control facility.




| Pipe Penetration for Launch Control Facility | | | | | | |
|---|---|---|---|---|---|---|
| Pipe Size | Sleeve Size | Sched. | L | t | Remarks | D |
| 3/4" | 6" | 160 | 5'-0" | 3/4" | insulated | 12" |
| 1" & 1-1/2 | 8" | 160 | 5'-0" | 1" | insulated | 12" |
| 3" | 10" | 160 | 5'-0" | 1-1/8" | insulated | 12" |
| 6" | 12" | 120 | 6'-0" | 1-1/4" | insulated | 12" |

| Pipe Penetration for Launch Facility | | | | | | |
|---|---|---|---|---|---|---|
| Pipe Size | Sleeve Size | Sched. | L | t | Remarks | D |
| 3/4" | 6" | 80 | 3'-0" | 1/2" | not insulated | 9" |
| 1-1/2" | 6" | 80 | 3'-0" | 1/2" | not insulated | 9" |
| 2" | 8" | 80 | 3'-0" | 1/2" | insulated | 9" |
| 4" | 8" | 80 | 3'-6" | 1/2" | not insulated | 9" |

Figure 5. Pipe penetration for launch control and launch facilities.




Legend

—— permanent displacement at surface

– – – – permanent displacement at a depth of 8 feet from sand shaft data

o permanent structure displacement at top

Figure 6. Permanent horizontal displacement versus distance (reference 14).

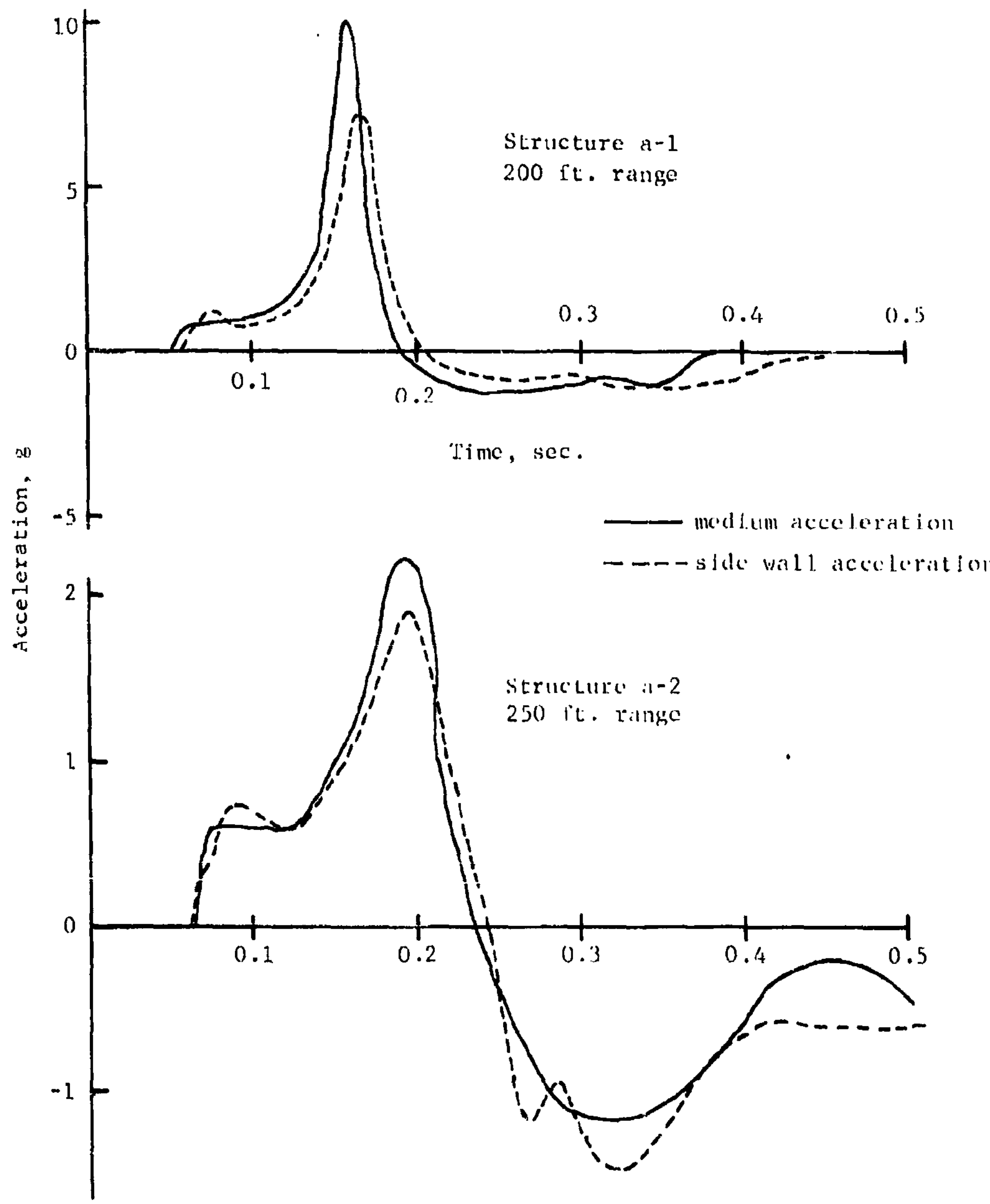



Figure 7. Comparison of structure and medium acceleration (reference 14).

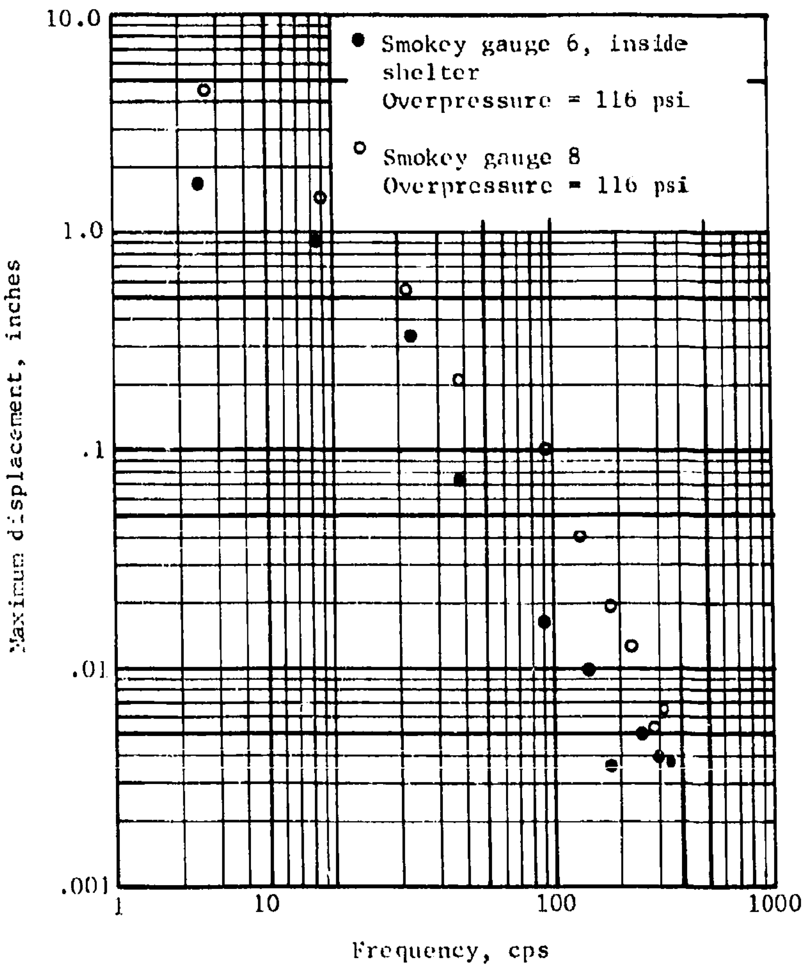



Figure 8. Displacement shock spectrum, vertical direction (reference 4).

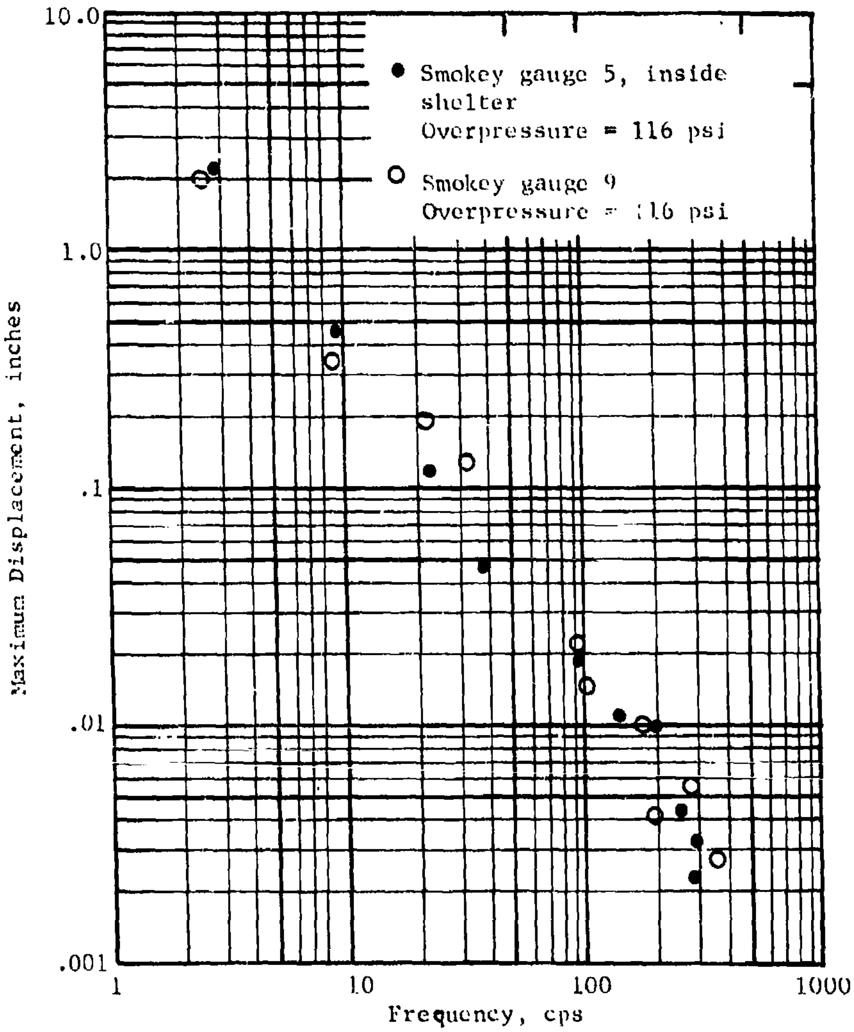



Figure 9. Displacement shock spectrum, horizontal direction (reference 4).

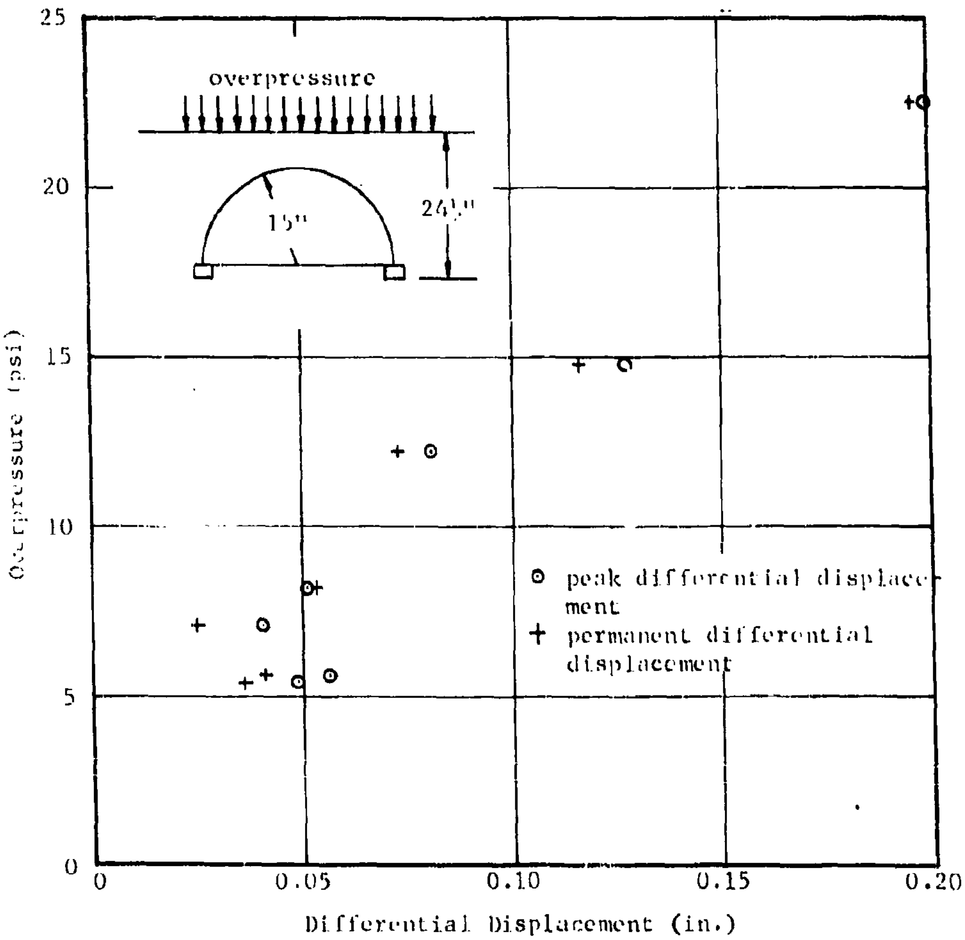



Figure 10. Overpressure versus peak and residual differential displacement between arch footing and adjacent soil.

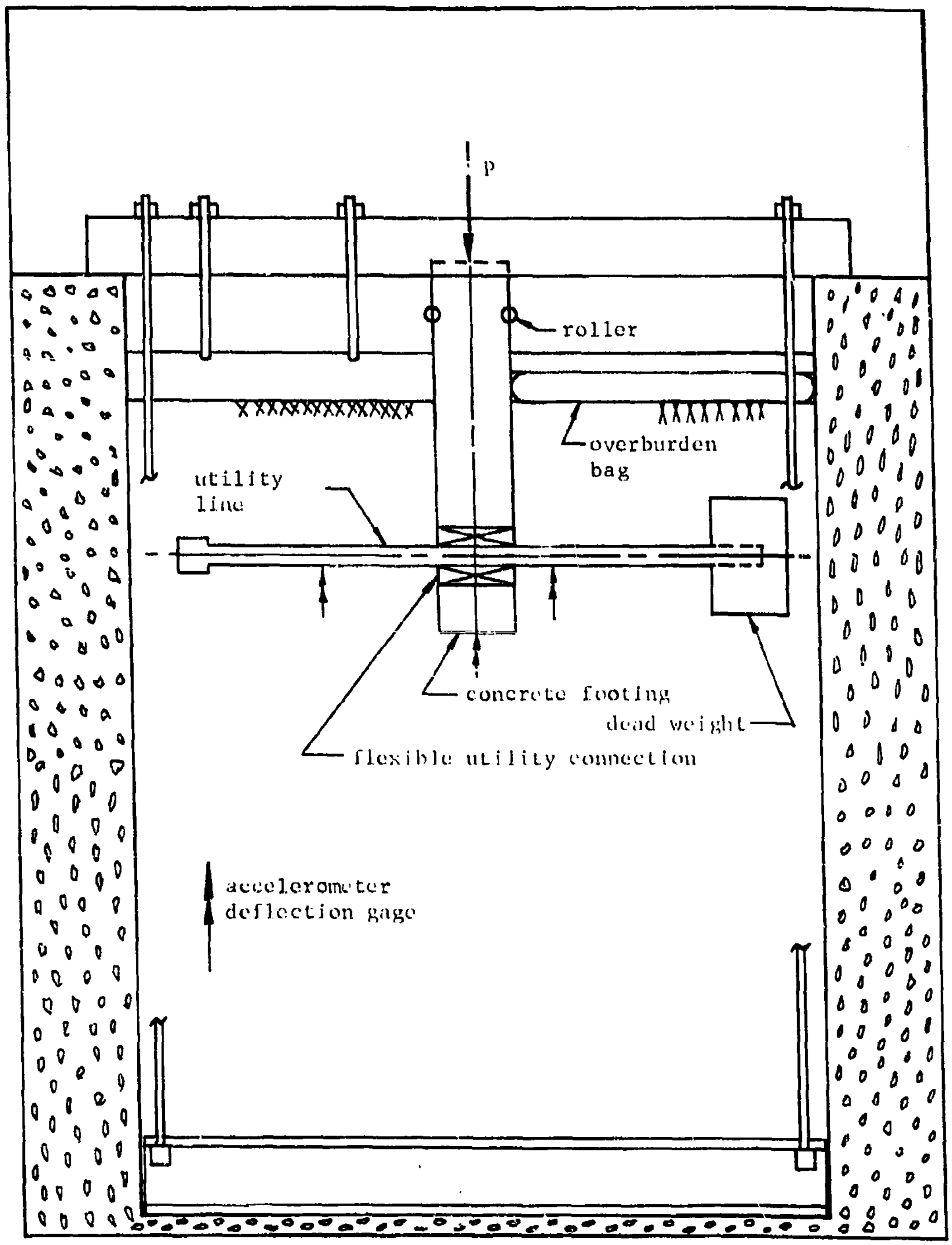



Figure 11. Setup for proposed testing of flexible utility connections in NCEL blast simulator pit.

UNCLASSIFIED

Security Classification

## DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>U. S. Naval Civil Engineering Laboratory<br>Port Hueneme, California | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified<br>2b. GROUP |

3. REPORT TITLE

FLEXIBLE UTILITY CONNECTIONS FOR UNDERGROUND PROTECTIVE SHELTERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final - March--December 1964

5. AUTHOR(S) (Last name, first name, initial)

Tomita, Hisao

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| 6 January 1965 | 31 | 15 |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br>b. PROJECT NO. Y-F011-05-02-304<br>c.<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>TN 678<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) |

10. AVAILABILITY/LIMITATION NOTICES

Qualified requestors may obtain copies of this report from DDC.

| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
|---|---|
| | BuDocks |

13. ABSTRACT

A brief investigation was made of current flexible utility connection designs for buried protective shelters, design criteria for the connections, and information on differential soil-structure displacements caused by nuclear explosions.

Some designs of flexible utility connections were found, but no design criteria were found. Only a meager amount of information was found on differential soil-structure displacements.

A recommendation is given to evaluate flexible utility connections.

DD FORM 1 JAN 64 1473 0101-807-6800

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Design | 8 | | | | | |
| Flexible | 0 | | | | | |
| Utility connections | 8,9 | | | | | |
| Subsurface structures | 4 | | | | | |
| Buried | 0 | | | | | |
| Shelters | 4 | | | | | |

## INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

UNCLASSIFIED

Best Available Copy